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NAVORD REPORT 1100

71955
A METHOD FOR THE OBSERVATION OF THE VORTICITY PROFILE BEHIND
EXPLOSIVE PRODUCED SHOCKS IN AIR

16 DECEMBER 1953



U. S. NAVAL ORDNANCE LABORATORY
WHITE OAK, MARYLAND

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A METHOD FOR THE OBSERVATION OF THE IONIZATION PROFILE BEHIND
EXPLOSIVE PRODUCED SHOCKS IN AIR

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ABSTRACT: A method for the observation of the ionization profile behind explosive produced shocks in air is described. Preliminary measurements of a qualitative nature of the shocks produced by the detonation of small quantities of dextrinated lead azide are presented and discussed. It is found that the region of maximum ionization for these shocks is at some distance behind the shock front.

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WHITE OAK, MARYLAND

16 December 1953

The physical properties of the disturbed region immediately behind explosive produced shocks in air have been found to be related to the ability of the disturbance producing explosive to initiate other explosives. It is the purpose of this report to present the results of some preliminary tests which were designed to test the feasibility of observing the ionization profile immediately behind the explosive produced shock fronts. The method described looks promising and may prove to be a useful research tool. The results are preliminary in character and are presented for information only. The author wishes to acknowledge the general advise and encouragement of Mr. R.H. Stresau and the help of Mr. C. Goode with the electronic design and construction. This work was done as part of the program under Task Assignment NOL-B2c-1-1-54, Initiation and Detonation of Explosives, and is a continuation of the work reported in NavOrd Reports 2132 and 2283.

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Captain, USN
Commander


J. E. ABLARD
By direction

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INTRODUCTION

In many types of explosive experiments, references (a) through (c), the ionization produced by the detonation of primary and high explosives is used to start and stop electrical circuits by shorting ionization probes. In these systems, current flows through the ionized region produced at and behind shock fronts in air. It is, therefore, of interest to obtain more detailed information about the conductivity of the air at the shock front and immediately behind it. Furthermore, it is probable that the pressure and temperature profiles and distributions in time and space of this air, which are directly related to the initiating ability of a detonating explosive, references (d) and (e), are also closely related to the ionization in the region behind the shock. It has been shown, reference (e), that some complicated integral of the ionization behind the air shock produced by the detonation of lead azide correlates well with the ability of the lead azide to initiate confined tetryl across an air gap. A method for the observation of the ionization profile behind explosive produced shocks in air is described in this report and some results which indicate that the method is feasible are presented.

EXPERIMENTAL DETAILS

The Probe:

The type of measurement which we wish to make requires a probing system which will remain fixed in space and undamaged and which will detect electrically the ionization in the compressed air as the air passes the probe. For this purpose the following design, Figure 1, was used. Two brass cylinders 1.000 inch in diameter with axially centered holes 0.150 inch in diameter were placed end to end as shown and insulated from each other with electrical tape 0.010 inch thick. A hole was cut in the tape slightly larger than in the brass and placed in line with the holes in the brass as shown. Brass screws were fixed in the cylinders so that electrical contact to them could be easily made.

The Explosive Charge:

The explosive charge holder used in these experiments is illustrated in Figure 2. Twenty-five milligrams of dextrinated lead azide were pressed into the plug element under a pressure of 4,000 psi. The plug element was then crimped into place in a brass cylinder with the dimensions shown.

The Firing Circuit:

The firing circuit consisted of a 45 volt battery and a 10 microfarad condenser connected in parallel to each other and in series with

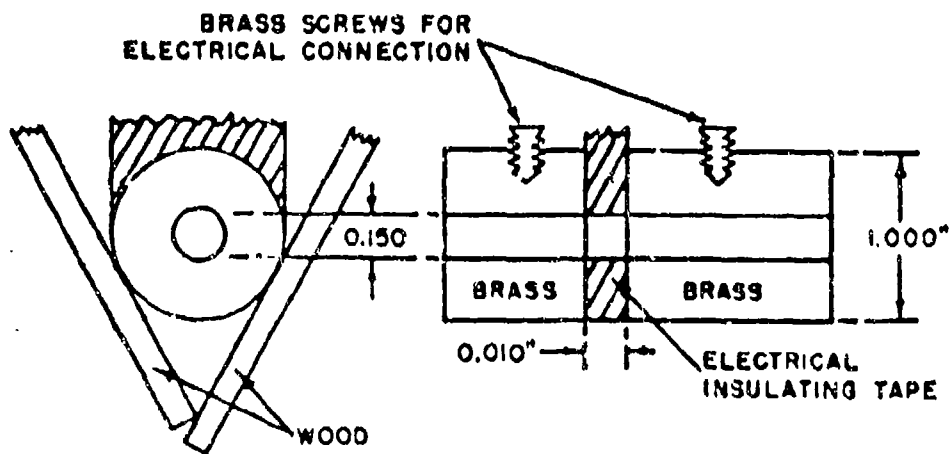


FIG. 1 DETECTION PROBE

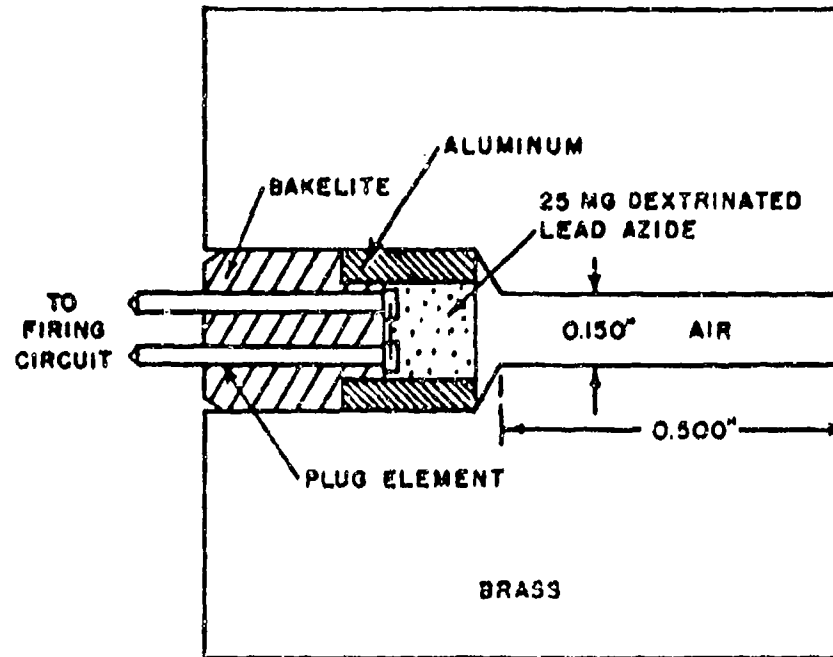


FIG. 2 EXPLOSIVE CHARGE HOLDER

a switch and the heating wire of the plug element.

The Complete System:

The complete system is shown schematically in Figure 3. A simple condenser discharge circuit was arranged so that a resistance, R, and an open gap, G, (our probe) were in series with a condenser, C, charged to a voltage, V. The time RC was large enough so that when the gap G was shorted, RC was very long compared to the time during which we wish to observe the current flow in the circuit. In Figure 4 an oscilloscope trace of the voltage across R during the first 10 microseconds of current flow after shorting the gap G is shown.

Our observation of the conductivity of the compressed air at and behind the shock front was made in the following manner, see Figure 3. The explosive holder was connected to the firing circuit. The probe gap was placed at the distance x from the explosive-air interface by choosing a suitable length for the "A" piece of the probe and placing the probe directly in contact with the explosive holder. The explosive holder and the "B" piece of probe were insulated from each other by electrical tape and wood as shown in Figures 1 and 3. The "A" piece of the probe and one side of the condenser were connected to ground. The "B" piece of the probe was connected to the high side of the condenser through the resistance R as shown in Figure 3. The deflecting plates of a Tektronix oscilloscope No. 517T were connected across the resistance R so that the variation of the voltage across R as a function of time could be observed. The 10 microsecond sweep scale was used and the triggering circuit arranged so that the sweep would be started by the first appearance of a voltage across R so that we would be able to observe the voltage variation across R during the first 10 microseconds of current flow through the probe circuit. The condenser C was then charged to 70 volts and the switch placed in position (2) as shown in Figure 3.

When the firing circuit switch was closed, the heating element of the explosive holder initiated detonation in the lead azide. When the detonation shock reached the explosive-air interface a shock was formed in the cylindrical air tube. This air shock then propagated down the tube toward the probe with a pressure profile like that shown in Figure 5. The pressure and the temperature are a maximum at the shock front and decrease together behind the shock front. At the boundary between the compressed air and the reaction products which act as the piston which is driving the shock, the temperature takes a sudden drop but the pressure continues its gradual decrease. As this decaying shock propagates down our cylindrical tube the pressures and temperatures at and behind the shock front decrease as more and more air is picked up, compressed, and pushed along by the reaction products.

It is reasonable to expect also that the conductivity of the air decreases in somewhat the same manner as the pressure and temperature

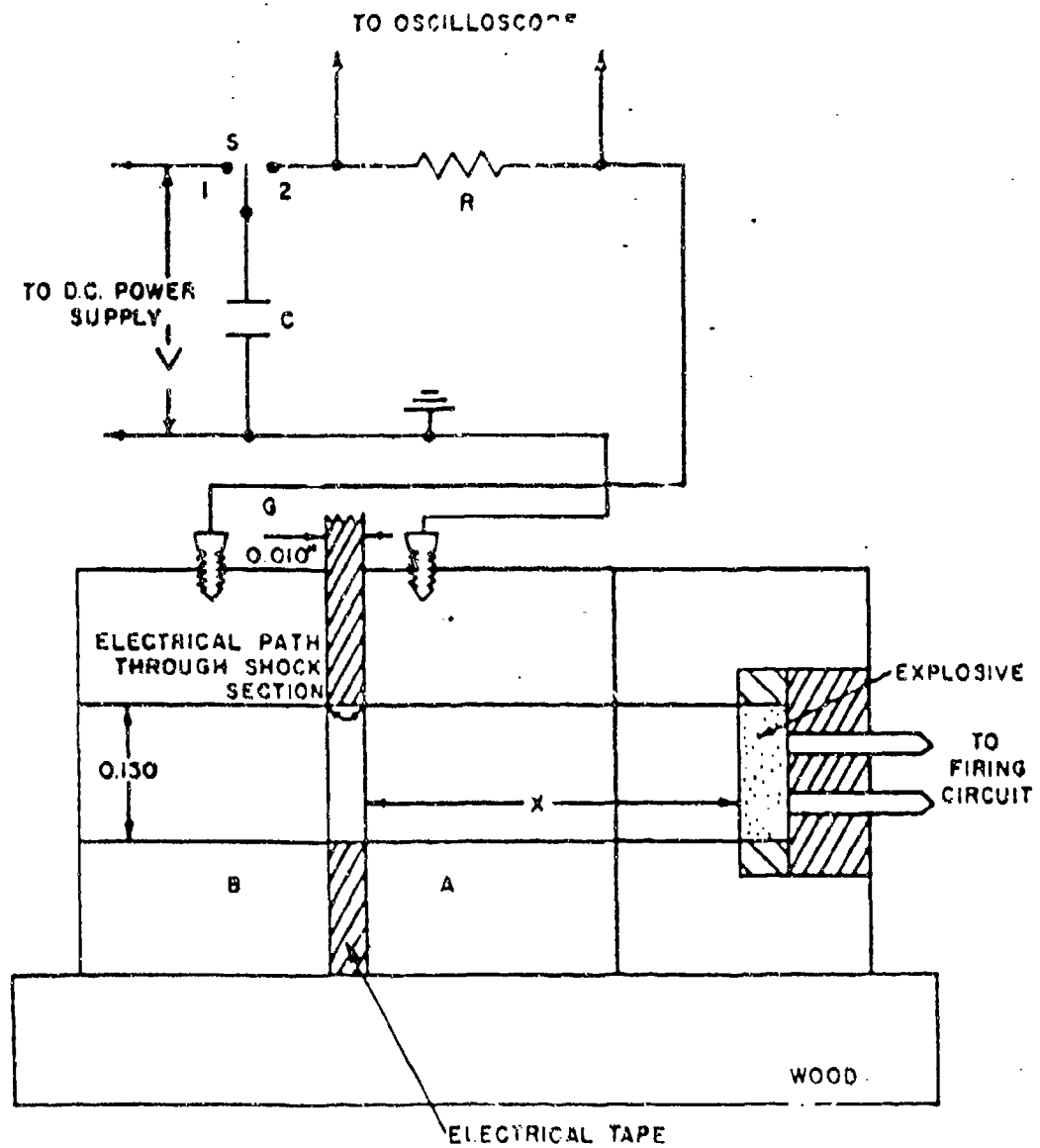


FIG. 3 THE COMPLETE SYSTEM

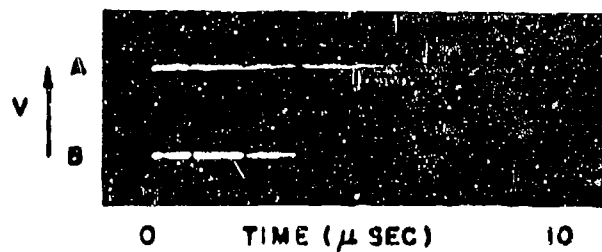


FIG. 4 OSCILLOSCOPE TRACE (A) OF VOLTAGE VARIATION ACROSS R OF FIG. 3 DURING FIRST 10 MICROSECONDS OF CURRENT FLOW AFTER SHORTING GAP G. TRACE (B) IS BASE LINE DUE TO RETRIGGERING

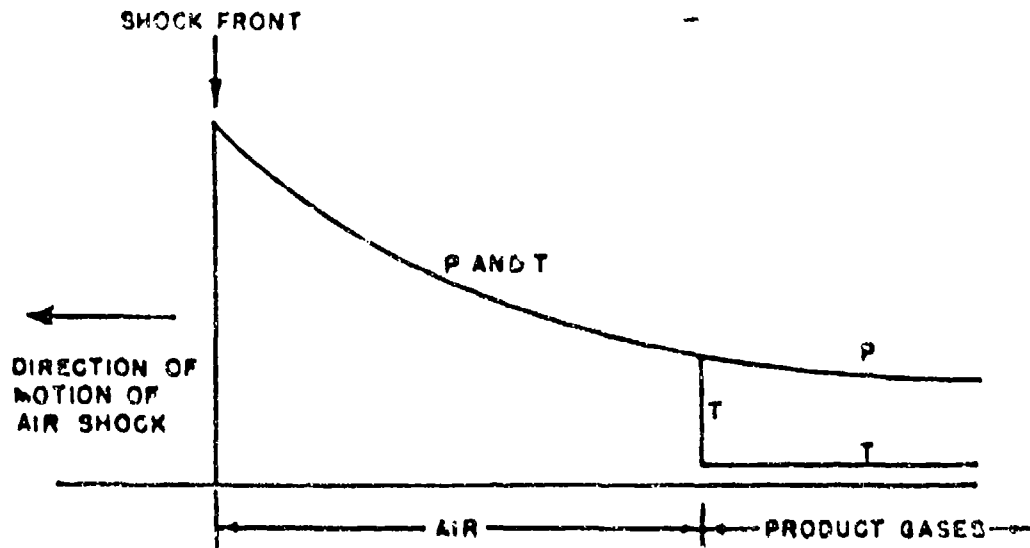


FIG. 5 PRESSURE AND TEMPERATURE PROFILE
BEHIND AN EXPLOSIVE PRODUCED AIR SHOCK

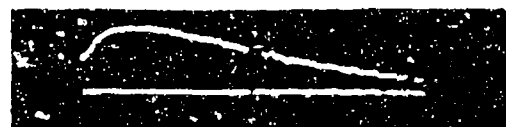
VOLTAGE DROP ACROSS, R → THIS IS PROPORTIONAL TO THE
CONDUCTIVITY OF THE COMPRESSED AIR BEHIND THE SHOCK FRONT



(A)

X (INCHES)

3.00



(B)

2.500



(C)

1.500



(D)

1.000



(E)

0.750

VERTICAL SCALE
IS NOT LINEAR

0 4 8

TIME AFTER SHOCK ARRIVAL AT PROBE (μ SEC)

THIS IS ROUGHLY PROPORTIONAL
TO DISTANCE BEHIND SHOCK FRONT

FIG. 6

as we move into the compressed gases behind the shock front. We find, however, that this does not appear to be the case.

RESULTS

In Figure 6 the results of measurements of a qualitative nature of the conductivity produced by the detonation of 25 mg of dextrinated lead azide for the system of Figure 3 are shown. These are oscilloscope traces on the 10 microsecond sweep scale of the Tektronix Model 517T. The vertical deflections are proportional to the voltage across the resistance R, of Figure 3 and consequently to the current through R and hence to the conductivity of the electrical path through the ionized gas across the probe.

It is very clear that the maximum conductivity is not at the shock front.

DISCUSSION OF RESULTS

The oscilloscope traces of Figure 6 may be interpreted as qualitative graphical representations of the variation of the conductivity of the compressed air at and immediately behind the shock front. When $x = 3.500$ inches, that is, when the probe gap is 3.500 inches from the explosive-air interface, the conductivity of the air at the probe takes a sudden small jump upon the arrival of the shock front. Then for about three microseconds the conductivity increases as we look into the compressed gases behind this front. Measurements of the air shock velocity at the probe indicate that it is about 2800 meters/second. According to some unpublished calculations by S. G. Reed*, this time is of the right order of magnitude for the time for the ionization to reach equilibrium when produced by a shock of this velocity. When the distance between the explosive-air interface and the probe is reduced and consequently observations of higher velocity shocks are made, the initial ionization upon the first arrival of the air shock at the probe increases with increasing shock intensity. Furthermore, the time to reach equilibrium was observed to decrease with increasing shock velocity. All of this is consistent with the theoretical speculations of W. Doring, reference (f).

It appears then that the method described can successfully detect the conductivity of the ionized gases at and immediately behind explosive produced air shocks. The effect of the probe geometry upon the system has not yet been determined.

*Naval Ordnance Laboratory, Aeroballistic Research Department, Hyerballistics Division.

NAVORD Report 3589

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